

Chapter 5

Conversion of CASTNet Concentrations from Standard to Local Conditions



IRL141, FL

Atmospheric concentrations at CASTNet sites have been historically measured, analyzed, and presented at standard temperature and pressure. In early 2003, to make the CASTNet data set comparable to other monitoring efforts such as IMPROVE, the entire database of CASTNet concentrations was converted to values based on local temperature and pressure conditions. The conversion process involved applying correction factors based on the differences in measured temperature and estimated pressure levels when compared to standard values. Because pressure is not directly measured at CASTNet sites, elevation is used as a surrogate to determine the pressure correction factor. The resulting changes in concentrations are significant at high elevation sites ($\sim 20 - 25\%$) and relatively minor at sites closer to sea level ($\sim 0 - 5\%$). Using concentrations based on local conditions has no effect on previously published trend analyses; conclusions drawn from these analyses remain valid.

From its inception as NDDN in 1986, atmospheric concentrations at CASTNet stations have been measured and reported at standard temperature and pressure (STP) conditions. Other monitoring networks in the United States, such as IMPROVE and the $PM_{2.5}$ speciation network, report atmospheric concentrations at local temperature and pressure conditions. Atmospheric concentrations at CASTNet sites were converted from STP to local conditions in early 2003 in order to make the CASTNet data set compatible with these other monitoring efforts. The converted data set was used for all analyses in this report,

including the estimates of dry and total deposition. This chapter describes the method used for the conversion and analyzes the differences between the concentrations reported at local and standard conditions.

Flow rates through the CASTNet three-stage filter packs are operated and calibrated based on STP conditions. Therefore, the aggregated flow volume for a specific sample is representative of standard conditions, and a calculated numerical factor is necessary to convert the flow volume to

local conditions. The conversion factor is based on the ideal gas law:

$$PV = nRT \quad (1)$$

where:

P = atmospheric pressure

V = volume

n = number of moles

R = universal gas constant (0.08206 L atm mol⁻¹ K⁻¹)

T = temperature

Based on the relationships in this equation, changes in temperature and pressure values from standard conditions [25 °C and 1 atmosphere (atm), respectively] to local conditions (variable temperature and pressure values) also changes the volume. Volume and temperature are directly related while volume and pressure are inversely related. In other words, when actual temperature values are greater than 25 °C, volume will increase and concentrations will decrease, and when actual temperature values are less than 25 °C, volume will decrease and concentrations will increase. The opposite case is true for changes in pressure. However, since atmospheric pressure is not currently measured at CASTNet sites, site elevation was used to estimate the difference in pressure between local and standard conditions. Changes in pressure due to synoptic scale meteorological patterns were not considered. Standard pressure is the pressure at sea level. Since pressure decreases with elevation, the pressure element of the conversion factor always acts to increase volume and decrease concentrations. No

CASTNet sites are located at elevations below sea level. Sites at BFT142, NC; EVE419, FL; and IRL141, FL are the lowest at 2 meters above sea level.

Volume at standard conditions is converted to volume at local conditions using the following relationship, which was derived from the ideal gas law (Equation 1):

$$V_{ltp} * P_{ltp} * T_{ltp}^{-1} = V_{stp} * P_{stp} * T_{stp}^{-1} \quad (2)$$

where:

V_{ltp} = volume at local conditions

P_{ltp} = pressure at local conditions

T_{ltp} = temperature at local conditions

V_{stp} = volume at standard conditions

P_{stp} = pressure at standard conditions

T_{stp} = temperature at standard conditions

The V_{ltp} can be derived:

$$V_{ltp} = V_{stp} * (T_{ltp}/T_{stp}) * (P_{stp}/P_{ltp}) \quad (3)$$

where:

T_{ltp}/T_{stp} = temperature factor

P_{stp}/P_{ltp} = pressure factor

The temperature factor is simply the actual temperature divided by standard temperature after both temperatures have been converted to Kelvin. The change of units to Kelvin causes the influence of the temperature conversion to be minor compared to the pressure factor since even dramatic seasonal temperature fluctuations are small when converted to Kelvin. The standard temperature, 25 °C, is equal to 298 degrees Kelvin (°K) converted. The dominant

pressure factor is calculated using the following formula, which incorporates the elevation of the site and assumes a hydrostatic atmosphere:

$$P_{stp}/P_{ltp} = 1/(\exp -[(E/8437)+(E/26621)^2]) \quad (4)$$

where:

E = elevation

Combining Equation 3 and Equation 4 and incorporating actual values for STP yields the following equation, which is used to convert the flow volume at standard conditions to local conditions:

$$V_{ltp} = V_{stp} * (T_{ltp}/298 \text{ K}) * (1/(\exp -[(E/8437)+(E/26621)^2])) \quad (5)$$

T_{ltp} for a specific sample is determined by finding the mean of all ambient temperature values measured during the sampling week. At least 70 percent of the hourly temperature values must be valid in order for the mean temperature to be used in the conversion. If the mean temperature for the sample period is not valid, the mean temperature for the month during which the sample was run is used. Again, a 70 percent completeness criterion is applied. If the mean monthly temperature is not valid, the historical weekly mean temperature is used. This value is calculated by determining the week containing the mid-point of the sample run and averaging all valid temperature values for this week for all years within the data set. In order to use this value, the data set must contain at least two years of temperature data for the specific site. If the historical weekly mean temperature is

unavailable, the mean temperature for the season during which the sample was run is used, again with a percent completeness requirement of 70 percent or better. Finally, if none of the mean temperature values are valid, the conversion is not performed, and there are no concentrations for the sample in the local conditions data set.

To examine the impact of the standard to local conditions conversion on analyses undertaken using CASTNet atmospheric concentrations, the standard and local conditions data sets were compared for each site for 2002. Figure 5-1 shows the actual differences and percent differences (in parenthesis) between annual mean atmospheric concentrations of SO_2 for 2002. Because the conversion factor is the same for all analytes for a specific sample, only differences for SO_2 are displayed. The percent differences are calculated as follows:

$$\% \text{ Difference} = (\text{Conc}_{ltp} - \text{Conc}_{stp}) / \text{Conc}_{stp} \quad (6)$$

where:

Conc. ltp = Concentration at local conditions

Conc. stp = Concentration at STP

The shading on the map in Figure 5-1 is based on the elevations of the CASTNet sites presented on the map. The shading is not intended to represent actual elevations between CASTNet sites, but is intended to provide a frame of reference for visualizing the influence of the pressure factor on the conversion process. The map demonstrates that the sites with the highest elevations

experience the greatest changes in concentrations. Sites located in the Rocky Mountains illustrate this with the largest differences between annual means calculated for GTH161, CO and CNT169, WY, with decreases in mean concentrations of 24.1 percent and 26.2 percent, respectively.

In the eastern United States, sites along the Appalachians have the greatest differences, although elevations are much lower and therefore changes are smaller. GRS420, TN shows the greatest difference for the eastern sites with a decrease in annual mean concentration of 8.5 percent. Sites close to sea level, where the pressure factor is negligible, exhibit differences in mean concentrations that are positive (i.e., increases rather than decreases) due to the influence of the pressure factor. Because temperature values throughout the year are often lower than the standard temperature of 25 °C, the flow volume decreases, and the atmospheric concentrations increase. One exception is DEV412, CA where the temperatures throughout the year are often higher than 25 °C. The temperature factor acts to decrease the mean SO₂ concentration (-3.6 percent for the year).

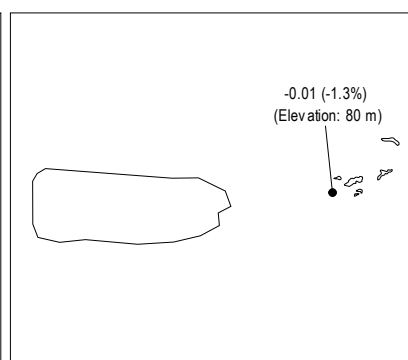
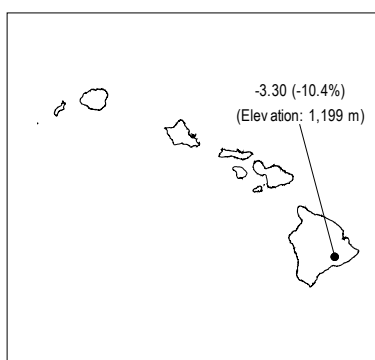
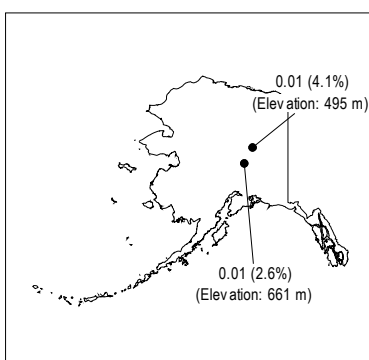
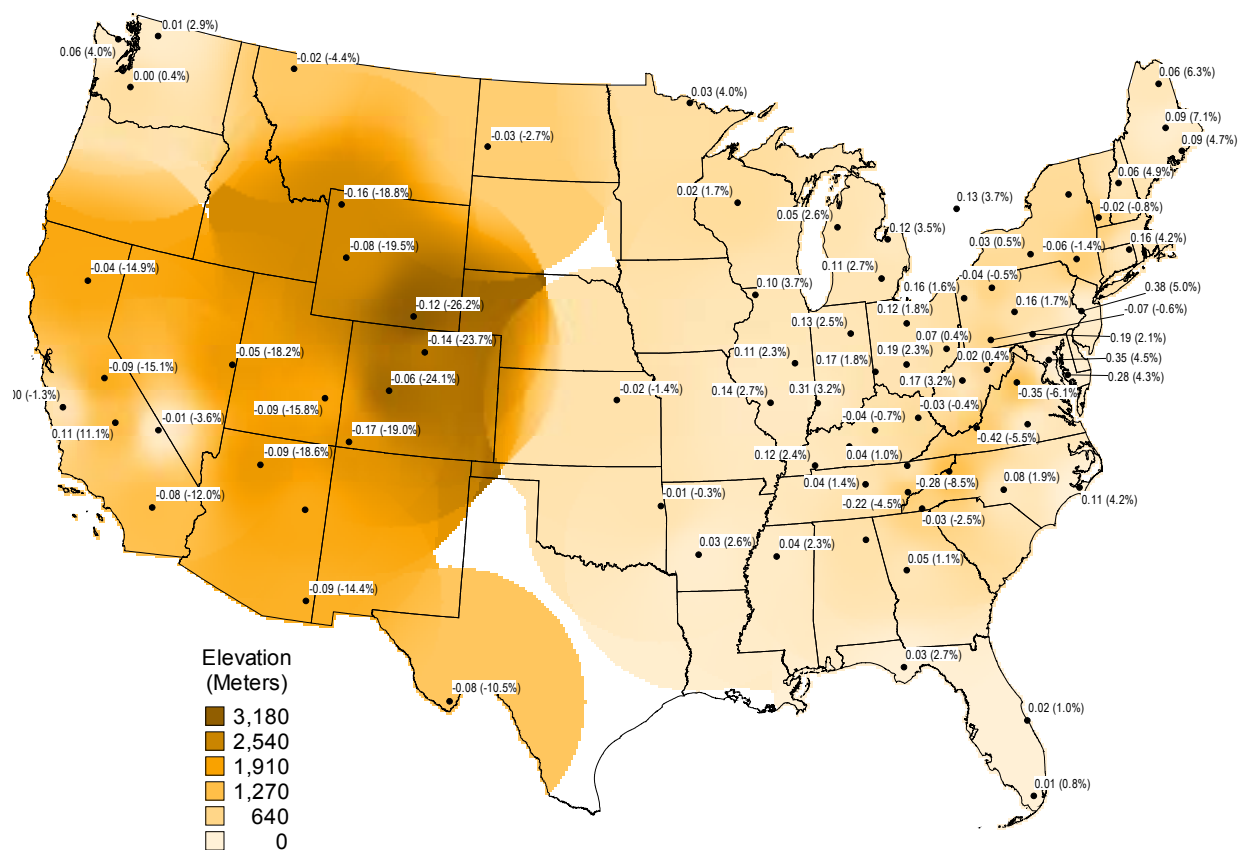
Figure 5-2 presents a comparison of time series using local conditions concentrations and standard conditions concentrations at

the 34 eastern reference sites. Also shown are the differences between the annual means. The differences are minimal, and the time series show the same pattern of changes over the 13 year period. The average percent difference between annual means is 1.5 percent with the greatest difference occurring between the 1994 mean concentrations (2.3 percent).

In conclusion, the conversion from atmospheric concentrations at standard conditions to atmospheric concentrations at local conditions makes the CASTNet data set comparable with other monitoring programs, which permits the use of new analysis techniques that combine analyte concentrations from different data sets. The differences between standard and local concentrations are greatest at high elevation sites, particularly those in the Rocky Mountain range. Differences are smallest at sites near sea level with temperatures that are close to 25 °C for much of the year. Comparisons of long-term time series indicate that analyses and conclusions presented in the past using CASTNet atmospheric concentrations at standard conditions are comparable to those presented in this report, which utilize concentrations at local conditions. Future reports will continue to use concentrations at local conditions.

The authors would like to recognize the work on this topic by Amy Kinner of EPA's Clean Air Markets Division (OAR/CAMD). Ms. Kinner prepared a comprehensive sensitivity analysis examining the conversion process and temperature replacement routine that was the basis for the protocol described in this chapter. We greatly appreciate her efforts and cooperation.

Figure 5-1. Actual and Percent Differences between Annual Mean Concentrations for 2002 at Local and Standard Conditions.



Percent differences are shown in parenthesis. Units for calculated differences are $\mu\text{g}/\text{m}^3$.

Figure 5-2. Comparison of Time Series Developed using Concentrations at Local and Standard Conditions

